PETROLEUM SOCIETY
CANADIAN INSTITUTE OF MINING, METALLURGY & PETROLEUM

PAPER 2004-144

CANADIAN INTERNATIONAL
PETROLEUM CONFERENCE

Production Optimization of Hassi R'mel Oil Rim Using Gas-Lift Approach

R. RECHAM, D. BENCHERIF
PED/Sonatrach Inc.

This paper is to be presented at the Petroleum Society's 5th Canadian International Petroleum Conference (55th Annual Technical Meeting), Calgary, Alberta, Canada, June 8 – 10, 2004. Discussion of this paper is invited and may be presented at the meeting if filed in writing with the technical program chairman prior to the conclusion of the meeting. This paper and any discussion filed will be considered for publication in Petroleum Society journals. Publication rights are reserved. This is a pre-print and subject to correction.

Abstract

This paper demonstrates the benefits to be gained from performance analysis of gas-lifted vertical and horizontal wells in Hassi R'mel oil rim, where significant incremental oil production rate can be achieved as water-cut increases and reservoir pressure declines by a comprehensive approach to the problem of gas-lift production optimization.

An artificial-lift method in which gas is injected into the production tubing to reduce the hydrostatic pressure of the fluid column. The resulting reduction in bottomhole pressure allows the reservoir liquids to enter the wellbore at a higher flow rate. The injection gas is typically conveyed down the tubing-casing annulus and enters the production train through a gas-lift valves. The gas-lift valve position, operating pressures and gas injection rate are determined to ensure maximum well productivity by specific well conditions.

The gas lift software used provides the ability to accurately design and maintain efficiency of gas lift production systems, by combining data acquisition and automation with proven gas lift engineering techniques. Additionally, root causes of failures can be systematically identified using sensitivity analysis tools.

Combined well and flowline performance was analyzed with a multiphase network hydraulic simulator that determined maximum transport capacity of the well and flowline system while ensuring that reservoir simulator, wellbore, and facilities constraints were met.

Introduction

The Hassi R'mel field is located approximately 500 kilometers South of Algiers in the Northern Grand Erg occidental of the Algerian Sahara. The Hassi R'mel field was discovered in November 1956 by the drilling of well HR-1. Early evaluations of the discovery revealed it to be one of the largest gas fields in the world which has an oil rim existing primarily along the Eastern and Southern margins of the field.

The reservoir of Hassi R'mel oil rim, contains thin oil columns of 30 feet average overlain by a large gas cap with bottom aquifer support.

Water and gas coning are serious problems in many oil field applications, where the production of water and gas from a thin oil reservoir is a common occurrence, which increases the cost of producing operations, and reduces the efficiency of the depletion mechanism and the overall recovery.

In water-coning systems, the viscous forces are caused by pressure drawdown near the wellbore which results as a consequence of fluid production, and the gravitational forces arise from the density difference between two fluids which tend to counterbalance the viscous forces, if the viscous forces exceed the gravitational forces than a cone is formed and grows up toward the perforated interval until water breaks into the wellbore.

Many horizontal wells have been drilled in addition to vertical wells in Hassi R'mel oil rim based on the simulation study and economic analysis, which was conducted to investigate the optimum number of vertical and horizontal wells (enhance reservoir contact and thereby enhance well productivity) to be drilled in Hassi R'mel oil rim.

The drilled and completed wells were expected to flow under naturally occurring pressures, but over a period of time in the life of those wells, the flow of some wells ceased and other declined to a point that are uneconomical as water cut increases and reservoir pressure declines.

Artificial lift is chosen as a method to employ in oil wells production as supplement to reservoir energy when the natural energy can no longer sustain production of crude oil from reservoir to the surface.

This paper demonstrates that significant incremental oil production can be achieved by a comprehensive approach to the problem of a continuous gas lift production optimization.

Statement of the Problem

For the Hassi R'mel oil rim recovery of the oil is difficult because water coning results in low oil production rates as reservoir pressure declines. The coned water competes with oil in the separation facilities and thus reduces production rates significantly.

Objective of the Study

The predominant objective of this study is to increase oil production rate in weak wells where flowing conditions are less favorable by continuous gas lift application. The object is to lower the weight of the fluid column in the tubing (assuming wellhead back pressure and tubing size are fixed) by the aeration of the fluid column with injection gas.

The Gas-Lift Concept

The theory behind continuous flow gas lift design is quite simple. It allows injection of gas in the production string to aerate the producing fluids which in turn lowers the bottom hole flowing pressure(BHFP). Any reduction in BHFP causes the reservoir to respond with increased flow rate. Consequently, once the piping system is fixed, the extent of reduction in the BHFP depends on two parameters, the amount of gas injected and the depth of injection.

Historically, optimum gas injection was defined as, "the volume of injected gas that results in the maximum production rate". Today, efficient use of lift gas ha become very important, and the optimum should be assigned to the point where an incremental expense for gas injection is equal to the incremental revenue produced at that injection rate.

The determination of the optimum gas distribution for each gas lift well in a reservoir becomes more significant when there is not enough available gas to supply all the producing wells; in this case, the gas should be allocated to those wells that are the most productive.

Historical Production of Hassi R'mel oil rim

The Hassi r'mel oil rim consists of four blocks related each to an oil treatment center. The production performance of the four blocks and the total block during the period where most recent wells have been drilled are illustrated on Figure 1 through 5 where the annual average production performance of each block and the total block are summarized on tables 1 through 5.

Table1: annual average production performance of block 1

Year	GOR (m3/m3)	Water-cut (%)	Oil Rate (m3/d)	Np 10^3 (stm3)
2000	3109	32	511	3414
2001	3170	37	507	3599
2002	2967	30	470	3771
2003	3440	40	456	3859

Table2: annual average production performance of block 2

Year	GOR (m3/m3)	Water-cut (%)	Oil Rate (m3/d)	Np 10^3 (stm3)
2000	1965	31	480	1179
2001	1390	24	656	1418
2002	1716	27	471	1590
2003	1814	28	456	1756

Table3: annual average production performance of block 3

Year	GOR (m3/m3)	Water-cut (%)	Oil Rate (m3/d)	Np 10^3 (stm3)
2000	361	27	146	1357
2001	396	26	175	1421
2002	277	38	226	1504
2003	273	35	290	1610

Table4: annual average production performance of block 4

Year	GOR (m3/m3)	Water-cut (%)	Oil Rate (m3/d)	Np 10^3 (stm3)
2000	4465	9	193	533
2001	4395	1	231	617
2002	3752	2	279	719
2003	3493	8	270	818

Table5: annual production performance of total blocks

Year	GOR (m3/m3)	Water-cut (%)	Oil Rate (m3/d)	Np 10^3 (stm3)
2000	2475	25	1330	6483
2001	2338	22	1569	7056
2002	2178	24	1447	7584
2003	2255	28	1472	8121

Remark: table 5 summarizes the production performance of the total blocks showing that there is a need to gas lift production optimization since the oil production rate decreased while adding new wells in Hassi r'mel oil rim.

The Continuous Gas-Lift Performance application

The method in studying the system performance curves are constructed by plotting the daily production oil rates versus the daily gas injection rates. Where optimum gas injection and oil production rates can be determined.

It is extremely important to note that in continuous gas lift, the daily oil production rate is directly linked to the daily gas injection rate (which is not the case for the intermittent gas lift).

Two examples will be showed of typical performance curves calculated for vertical and horizontal wells.

Performance Analysis of Well HW1 subjected to Gas-Lift as an Example for Horizontal Wells

The well HW1 provides an excellent example of the inherent flexibility of gas-lift as an artificial-lift method and demonstrates how production can be increased and optimized over the life of a well by application of an appropriate design technique.

The end of the historical production of this well shows that the well is producing at lower rate than expected with 77 m3/d and a GOR of 143 m3/m3 with only 4% of water-cut.

The simulation results show that the well cannot produce for water-cut greater than 20 % because of lack of energy. Since the horizontal well has a significant potential of oil production, to overcome this problem the well is subjected to gas-lift application, the simulation results shows that by injecting an optimum of 8000 m3/d of gas with 20% of water cut, the well can produce at an oil rate of 160 m3/d (Fig.6).

Many sensitivity runs have been performed for different water-cut to optimize daily gas injection and oil production rates illustrated on Figure 7 through 10. The optimum daily gas injection and oil production rates are summarized on table 6.

Table6: Optimum Gas-Lift Injection and oil Production Rate Results of Well HW1

Water-cut (%)	Gas Injection Rate (m3/d)	Oil Production Rate (m3/d)
4	0	77
20	0	0
20	8000	160
40	10000	80
60	15000	50
80	20000	22

Performance Analysis of Well HV1 subjected to Gas-Lift as an Example for Vertical Wells

The end of the historical production of this well shows that the well is producing at lower rate than expected with 72 m3/d and a GOR of 105 m3/m3 with 16% of water-cut.

The simulation results show that the well cannot produce for water-cut greater than 40 %. Since the vertical well has a significant potential of oil production, the well is subjected to gas-lift application, the simulation results shows that by injecting an optimum of 15000 m3/d of gas with 40% of water cut, the well can produce at an oil rate of 72 m3/d.

Many sensitivity runs have been performed for different water-cut to optimize daily gas injection and oil production rates which are summarized on table 7.

Table6: Optimum Gas-Lift Injection and oil Production Rate Results of Well HV1

Water-cut (%)	Gas Injection Rate (m3/d)	Oil Production Rate (m3/d)
16	0	85
40	0	0
20	8000	100
40	15000	72
60	15000	40
80	20000	20

Continuous Gas-Lift Application to Hassi R'mel Oil rim

The optimization problem to be solved consists in the assignment of the gas flow injection rates for 24 wells (07 horizontal wells and 17 vertical wells candidates to gas lift application) subjected to the constraints imposed by the performance curves of each well and to the corresponding available gas supply to the field.

These curves specify the relationship between the quantity of liquid produced and the injection gas flow rate for each individual well.

Many sensitivity runs have been performed for different water-cut to optimize daily gas injection and oil production rates. Table 8 through 13 show the optimum daily gas injection and oil production rates for different block areas including the total blocks.

Block 1 : 01 weak producing well and 04 shut-in wells

Block 2 : 03 weak producing wells and 02 shut-in wells

Block 3 : 03 weak producing wells and 08 shut-in wells

Block 4 : 03 weak producing wells

Total Block : 10 weak producing wells and 14 shut-in wells

Table8: Optimum Gas-Lift Injection and Oil Production Rate Results for the Producing Weak Wells at Current Water Cut.

	Block1	Block2	Block3	Block4	Total block
Oil Rate (m3/d)	48	247	141.5	114	550.5
Injection Gas Rate (m3/d)	15000	31000	68000	28000	142000

Table9: Optimum Gas-Lift Injection and Oil Production Rate Results for the Shut-in Wells at Current Water Cut.

	Block1	Block2	Block3	Block4	Total block
Oil Rate (m3/d)	450	234	719.5	0	1403.5
Injection Gas Rate (m3/d)	66000	12000	99000	0	177000

Table10: Optimum Gas-Lift Injection and Oil Production Rate Results for the Shut-in and Producing Weak Wells at Current Water Cut.

	Block1	Block2	Block3	Block4	Total block
Oil Rate (m3/d)	498	481	861	114	1954
Injection Gas Rate (m3/d)	81000	43000	167000	28000	319000

Table11: Optimum Gas-Lift Injection and Oil Production Rate Results for the Producing Weak Wells at 80% of Water Cut.

	Block1	Block2	Block3	Block4	Total block
Oil Rate (m3/d)	32	131	126	38	322
Injection Gas Rate (m3/d)	20000	52000	90000	50000	212000

Table12: Optimum Gas-Lift Injection and Oil Production Rate Results for the Shut-in Wells at 80% of Water Cut.

	Block1	Block2	Block3	Block4	Total block
Oil Rate (m3/d)	146	102.5	212.5	0	461
Injection Gas Rate (m3/d)	120000	270000	20000	0	347000

Table13: Optimum Gas-Lift Injection and Oil Production Rate Results for the Shut-in and Producing Weak Wells at 80% of Water Cut.

	Block1	Block2	Block3	Block4	Total block
Oil Rate (m3/d)	178	233.5	333.5	38	783
Injection Gas Rate (m3/d)	140000	79000	290000	50000	559000

The simulation results shows the benefits to be gained from performance analysis of gas lifted vertical and horizontal wells in Hassi R'mel oil rim.

A significant gain in oil production rate of 861 m3/d for the block 3 at current water-cut can be achieved by using gas-lift approach. Table 10 summarizes the optimum gas-lift injection and oil production rate results for the shut-in and producing weak wells for the total blocks at current water cut, whereas table 13 summarizes the same performance but at 80% of water-cut.

Summary

Gas-lift in an artificial method of lifting oil from a well to the surface in which high-pressure gas is injected into a point down-hole in order to lighten fluid (hydrostatic) column and reduce back-pressure on the formation.

Gas-lift helps to improve production through greater drawdown and this is achieved by means of valves mounted on the production tubing which provide admission of the gas into the tubing.

Artificial lift is chosen as a method to employ in oil wells production for Hassi r'mel oil rim as supplement to reservoir energy when the natural energy can no longer sustain production of crude oil from reservoir to the surface.

Conclusions

- This paper demonstrates that significant incremental oil production can be achieved by a comprehensive approach to the problem of a continuous gas lift production optimization.
- Numerous flowing wells show increased flow oil rates when placed in gas-lift.
- The optimum should be assigned to the point where an incremental expense for gas injection is equal to the incremental revenue produced at that injection rate.
- The determination of the optimum gas distribution for each gas-lift well in a reservoir becomes more significant when there is not enough available gas to supply all the producing wells; in this case, the gas should be allocated to those wells that are the most productive.

Acknowledgment

The author would like to thank the manager of the PED division of Sonatrach Inc (Algeria), for encouragement, all the means provided for the success of this work, and permission to publish this paper.

References

1. Liao.T., S.Zelimir. and D.R.Doty.: "Investigation of Intermittent Gas Lift Using Mechanistic Modeling" SPE 29454 (April 1995).

2. Leo.C.O., "Review of Advances in Gas Lift Operations" SPE 28292 (March 1994).

3. Avest.D., and Oudeman.P., "A Dynamic Simulator to Analyse and Remedy Gas Lift Problems" SPE 30639 (October 1995).

4. Cooksey.C. and Pool..M., "Production Automation System for Gas Lift Wells" SPE 29453 (April 1995).

5. Redden.J.D., Sherman.T.A.G. and Blann.J.R., "Optimizing Gas-Lift System" SPE 5150 (October 1974).

6. Martinez.E.R., Moreno.W.J. and Moreno.J.A., "Application of genetic Algorithm on the Distribution of Gas-Lift Injection" SPE 26993 (April 1994).

Fig.1 : Historical Production performance of Block 1

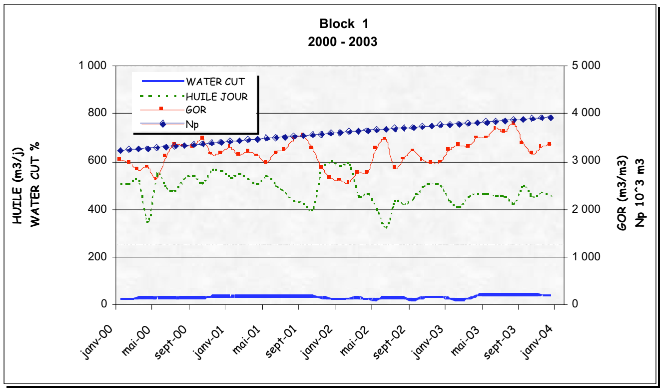

Fig.2 : Historical Production performance of Block 2

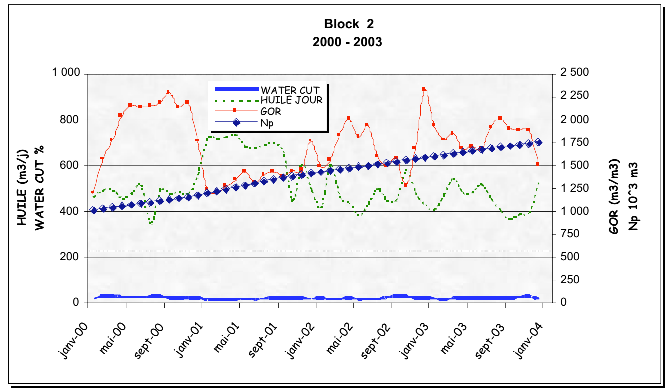

Fig.3 : Historical Production performance of Block 3

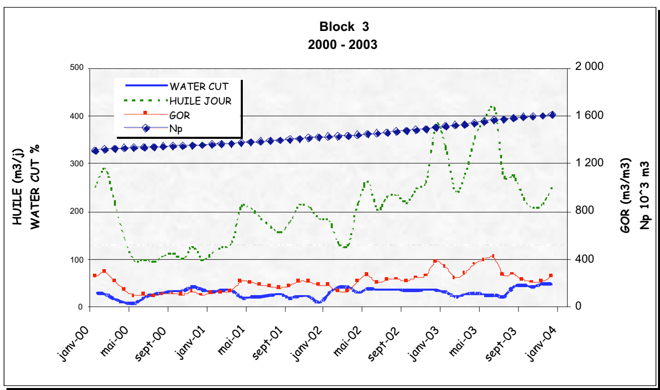

Fig.4 : Historical Production performance of Block 4

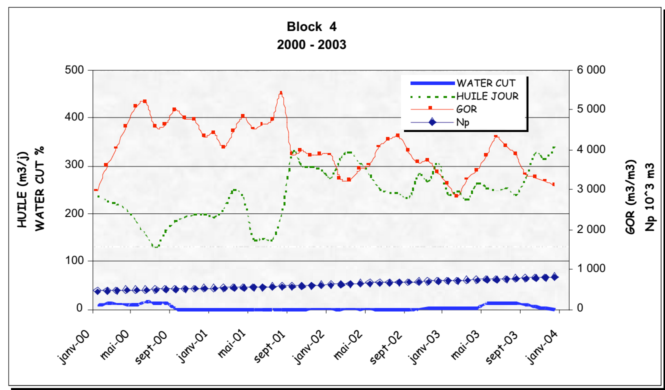

Fig.5 : Historical Production performance of total Block

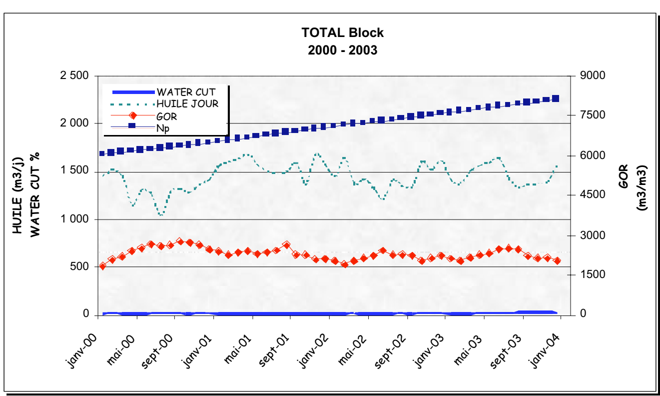

Fig.6 : Typical relationship Between Oil Production and Gas lift Injection Rate Horizontal Well HW1

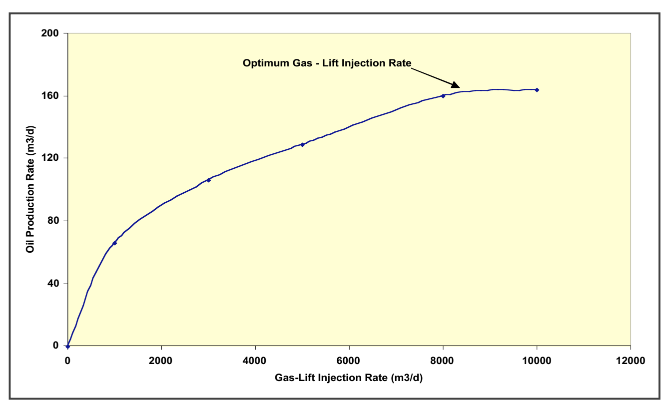

Fig.7 : Daily gas injection and oil production rate Simulation Results at 20% of Water-Cut.

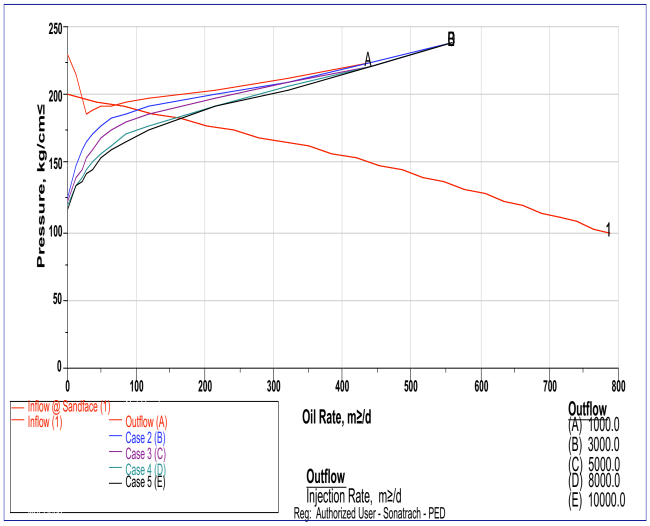

Fig.8 : Daily gas injection and oil production rate Simulation Results at 40% of Water-Cut.

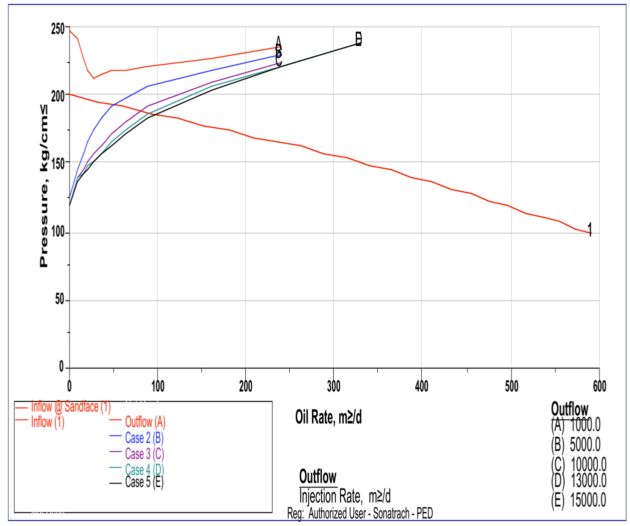

Fig.9 : Daily gas injection and oil production rate Simulation Results at 60% of Water-Cut.

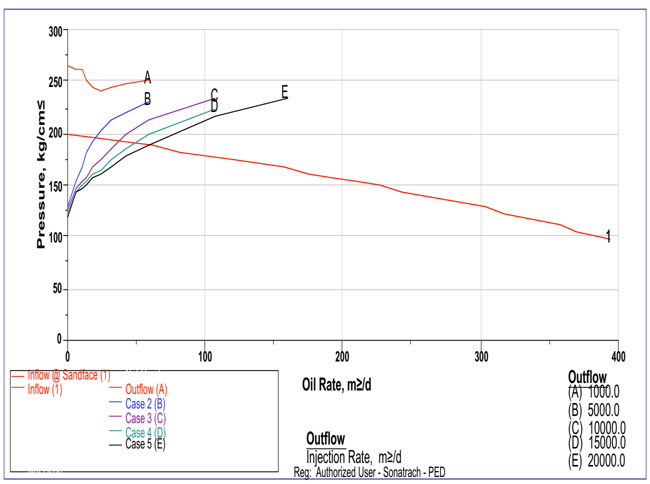

Fig.10 : Daily gas injection and oil production rate Simulation Results at 80% of Water-Cut.